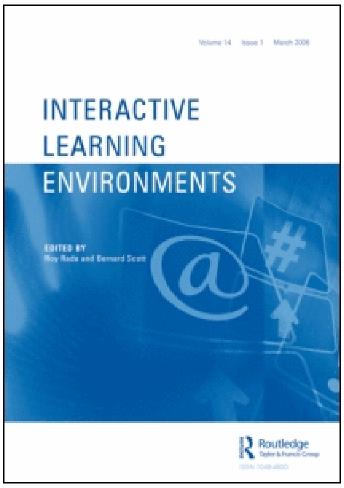

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Liesbeth Kester [a]; Paul A. Kirschner [b]
[a] Open University of the Netherlands, The Netherlands [b] University of Utrecht, The Netherlands

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Effects of fading support on hypertext navigation and performance in student-centered e-learning environments

Liesbeth Kester[a]* and Paul A. Kirschner[b]

[a]*Open University of the Netherlands, The Netherlands;* [b]*University of Utrecht, The Netherlands*

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Whether fading support for problems affects accuracy of hypertext navigation and problem performance is investigated in this study. In a student-centered e-learning environment conceptual support is added to help domain novices get an overview of the problem domain, while strategic support is provided to help domain novices get insight into the problem demands. It is assumed that such support helps learners because it lowers the cognitive load of navigation. This frees up cognitive capacity for learning provided that the support fades and becomes less intrusive as a function of learner expertise. It is hypothesized that fading support during practice helps learners navigate more accurately during practice and achieve a higher practice and test performance as compared to learners receiving full support or no support during practice. This study confirms the beneficial effects of fading support on navigation but no effects of fading were found on practice and test performance.

Keywords: hypertext navigation; graphic organizer; concept map; flow chart; fading support

Learners in student-centered e-learning environments construct their own knowledge. These learning environments provide meaningful contexts that combine skills and knowledge to facilitate this knowledge construction. The contexts provided in these environments are often problems to be solved or orienting goals to be reached (Hannafin, Hall, Land, & Hill, 1994; Hannafin & Land, 1997). They form the incentive for learners to consult electronic resources such as a linked hypertext document. A problem is that domain novices do not have an accurate notion of what there is to know about a particular problem (Ormrod, 2004). Therefore, they cannot determine what in the hypertext document (that is, problem or goal relevant information) might help them to solve the problem or reach the goal. The decisions made by learners on which information to use can result in misconceptions, especially when dealing with more complex problems or tasks (Hannafin, Land, & Oliver, 1999). In addition, research shows that properly perceiving the problem demands is also often problematic for domain novices. See Broekkamp, van Hout-Wolters, Rijlaarsdam, & van den Bergh (2002), Broekkamp, van Hout-Wolters, van den Bergh, & Rijlaarsdam (2004) for task demands in relation to test expectations;

*Corresponding author. Email: liesbeth.kester@ou.nl

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Luyten, Lowyck, & Tuerlinckx (2001) for task perception; Zumbach and Reimann (2001) for goal orientation. In general, finding specific information in hypertext documents could result in disorientation and cognitive overload (Conklin, 1987). So, support is needed to help these learners navigate through student-centered e-learning environments, find the right resources to solve the problem and, ultimately, construct their knowledge.

Two types of support are available to help learners reach this goal: conceptual support and strategic support (Hannafin et al., 1999). Conceptual support is meant to help learners decide what needs to be considered during problem solving. It should provide domain novices with an overview of the relevant concepts in the problem domain and their relations. Strategic support is meant to make learners aware of the problem solving strategies that can be used to solve the problem. It aims at giving domain novices insight into the problem demands (Kester, Kirschner, & Corbalán-Pérez, 2005). The support often found in electronic resources or linked hypertext documents takes the form of graphic organizers (for example, site maps) that represent the content of the hypertext document. The presence of these graphic organizers improves user navigation and learning (for an overview see Nilsson & Mayer, 2002; Robinson, 1998). In the research reported here, a concept map in which the important concepts in the problem domain and their relations are depicted provides the conceptual support. Concept maps have been successfully used for both knowledge acquisition (for example, as communication tools for organizing concepts) and cognitive processing support (for example, by providing multiple retrieval paths for accessing knowledge) (O'Donnell, Dansereau, & Hall, 2002). The strategic support is presented by a flow chart in which a systematic approach to problem solving (SAP) is depicted in a stepwise manner. A flow chart enables the representation of the goals and sub goals that have to be reached within each problem solving phase, together with the heuristics that may be used to reach those goals. A flow chart is particularly useful for indicating the *enabling relationships* between the (sub) goals (van Merriënboer, 1997; van Merriënboer & Kirschner, 2007). Research shows that such problem solving process support positively influences transfer efficiency, that is, with the help of this support learners are able to achieve a higher test performance while investing less mental effort than learners who do not have this support (van Gog, Paas, & van Merriënboer, in press).

It is believed that support in the form of graphic organizers helps learners because it lowers the cognitive load of navigation. This frees up cognitive capacity to learn the structure of the hypertext document's content (Nilsson & Mayer, 2002). This assumption has been indirectly confirmed in research by Nilsson and Mayer. They found that the presentation of explicit support (that is, low load) in the form of a graphic organizer depicting hierarchical and concurrent relationships led to better navigation and better learning than the presentation of implicit support (that is, high load) in the form of an alphabetical overview of related topics. However, they also found that the usability of graphic organizers changed over time. While explicit support might be useful for domain novices with ill-structured, ill-developed schemata, it might be less appropriate for domain experts who already possess structured, well-developed schemata. This effect is known as the expertise reversal effect (Kalyuga, Ayres, Chandler, & Sweller, 2003). It holds that the information provided by the support becomes redundant for learners who already possess relevant schemata, and presenting redundant information during practice impedes learning (Sweller, van Merriënboer, & Paas, 1998). To avoid this effect, the support should be diminished as expertise increases (fading). This enables the learners to allocate all of their available cognitive capacity to processes and information relevant for that learning, which in turn will have beneficial effects on learning outcomes (that is, navigation and performance).

In accordance with the expertise reversal effect, it is hypothesized that fading support by presenting less and less detailed graphic organizers during practice helps learners to: (1) navigate more accurately during practice; and (2) achieve a higher practice and test performance as compared to learners receiving full support during practice.

Method

Participants

Forty-one students (21 males and 20 females; age $M = 39.6$ and $SD = 11$) at the Open University of the Netherlands (OUNL) participated in this study. The participants were enrolled in Bachelor or Master programs from different departments of the OUNL, namely, cultural sciences, psychology, business studies, environmental studies, informatics and law. Participation made them eligible for 'winning' two OUNL-courses of choice via a raffle. They could access the experiment through the Internet from their own home at a self-chosen moment. All participants indicated that their English reading skills (the language the experiment was in) and their basic ICT skills such as opening a browser, navigating through a website, and so forth were average or above. None of the participants was familiar with the book: *Training complex cognitive skills: A four-component instructional design model for technical training* (van Merriënboer, 1997) which formed the subject matter used in this experiment. All of the participants reported themselves to be domain novices in the field of instructional design.

Materials

Mini-course instructional design

A mini-course on 'instructional design' was used for this experiment. For the mini-course a student-centered e-learning environment was developed which contained problems, a hypertext document that consisted of a number of sections of the aforementioned book, conceptual and strategic support depending on the experimental condition, and multiple choice questions. The content was related to the instructional design component 'learning tasks' of the four component instructional design model (4C/ID model). The context of the mini-course was formed by three problems in which the participants were taught the basics of designing a learning task for achieving a complex cognitive skill. Every problem contained a problem description aimed at eliciting an information need and information search behavior in the participants. The hypertext document could be navigated through by clicking on links in an outline of chapters and sections of the 4C/ID book. By consulting the proper information in the hypertext, the participants could learn more about the problem and based on this information could reason about possible solutions to the problem. The three problems reflected the three steps necessary for designing a learning task. Step 1 (problem 1) required the construction of a skills hierarchy consisting of the constituent skills that make up the complex skill to be achieved and was related to chapter 6 of the 4C/ID book. Step 2 (problem 2) required the development of case types that range from simple to complex and which consist of a number of learning tasks of equal complexity and was related to chapter 10 of the book. Finally, step 3 (problem 3) required the design of the actual learning tasks that differ in the amount of embedded support and was related to chapter 11 of the book.

Conceptual and strategic support

Two types of support were designed. Conceptual support was provided in the form of a concept map (see Figure 1a), which depicted the conceptual model of the problem domain to help the participants get an overview of it. More specifically, the concept map consisted of three central concepts: complex cognitive skill, case types and learning tasks. For each of these concepts the most important related concepts were given. Strategic support was provided in the form of a flow chart (see Figure 2a) that depicted a SAP of the problem domain along with some relevant heuristics to help participants gain insight in the problem demands. More specifically, eight steps

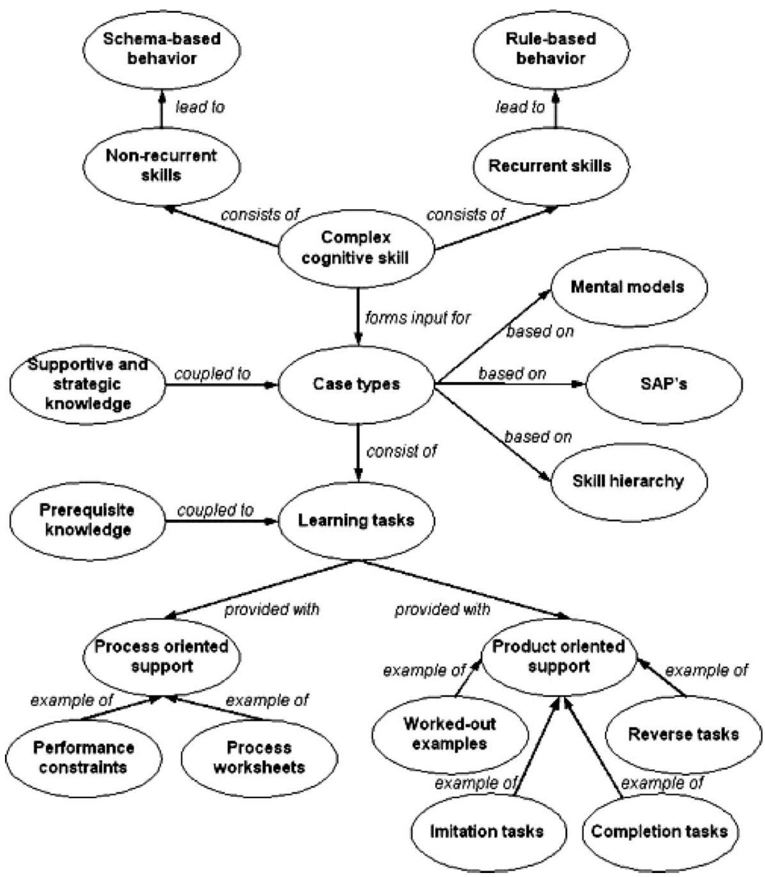

Figure 1a. Fading the conceptual support. The complete concept map presented together with problem one.

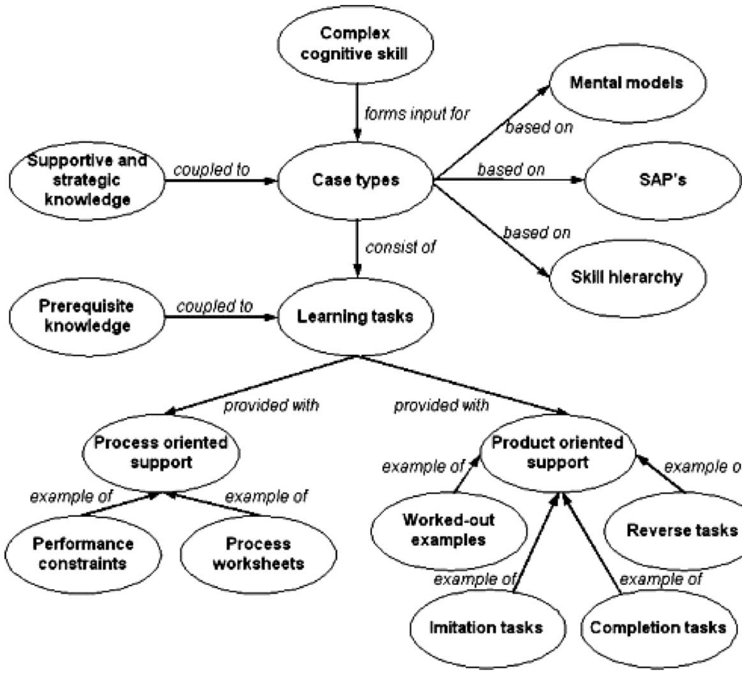

Figure 1b. Fading the conceptual support. The partial concept map presented together with problem two.

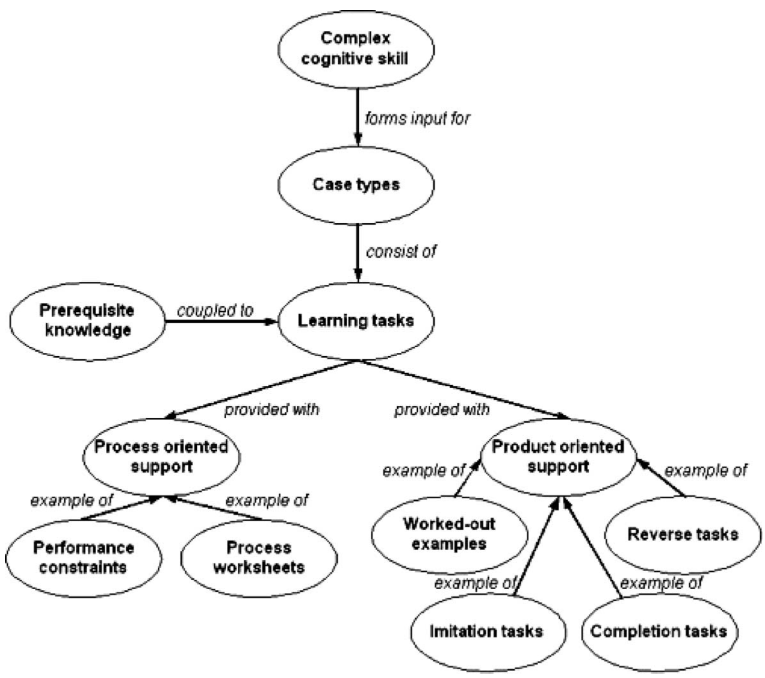

Figure 1c. Fading the conceptual support. The partial concept map presented together with problem three.

to design instruction for complex cognitive skill acquisition were given. Steps 1, 2 and 3 lead to the analysis of a complex cognitive skill into clusters of skills that can be trained. Steps 4, 5 and 6 lead to the determination and sequencing of case types which address the skill clusters and steps 7 and 8 result in the design of specific learning tasks. The steps were accompanied by heuristics that help to reach the goal of each step, for example, 'To determine the most authentic case type (step 4), watch expert behavior in a real life setting'.

A 2×2 factorial design with the factors conceptual support (faded, not faded) and strategic support (faded, not faded) was used. The participants were randomly divided over four conditions. In the 'conceptual support faded, strategic support faded' condition ($n = 12$) both support types are faded during practice; in the 'conceptual support faded, strategic support not faded' condition ($n = 11$) only the conceptual support is faded during practice; in the 'conceptual support not faded, strategic support faded' condition ($n = 10$) only the strategic support is faded during practice and, finally, in the 'conceptual support not faded, strategic support not faded' condition ($n = 8$) both support types are not faded during practice.

In the 'conceptual support faded' conditions, the first problem was accompanied by a concept map that consisted of the three central concepts – complex cognitive skill, case types and learning tasks – and their most important related concepts (see Figure 1a). The second problem was accompanied by a concept map which depicted the three central concepts but only the related concepts for 'case types' and 'learning tasks' were given (see Figure 1b) and in the concept map that accompanied the third problem, the three central concepts were given but only the related concepts for 'learning tasks' were specified (see Figure 1c).

In the 'strategic support faded' conditions, the flow chart that accompanied the first problem (see Figure 2a) contained the eight solution steps that lead to: (1) trainable skill clusters; (2) a sequence of case types; and (3) a series of learning tasks, and the related heuristics that help reach these goals. The second problem was accompanied by a flow chart that started from trainable skills clusters (that is, step 3: 'Cluster the skills into trainable units'; see Figure 2b) and omitted the heuristics related to steps 1, 2 and 3. Finally, the flow chart that accompanied the third problem started from a sequence of case types (that is, step 6: 'Design a sequence of case types') and omitted the heuristics related to steps 1 to 6 (see Figure 2c).

Navigation

The actions resulting from the participant's mouse clicks in the learning environment were logged, as was the time on task. Navigation-accuracy was calculated by dividing the frequency of correctly consulted sections per problem (that is, sections from chapter 6 for problem 1; chapter 10 for problem 2; chapter 11 for problem 3) by the total frequency of consulted sections per problem.

Practice items

Twelve practice items were administered to the participants (four for each problem). These practice items consisted of multiple choice questions with four answering options. Per problem, two multiple-choice questions were related to the problem and two to the relevant information that accompanied the problem.

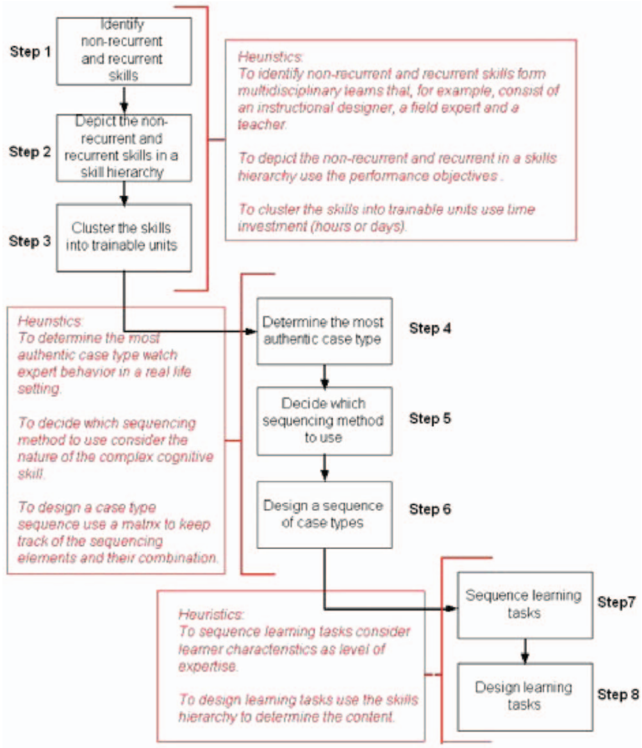

Figure 2a. Fading the strategic support. The complete flow chart presented together with problem 1.

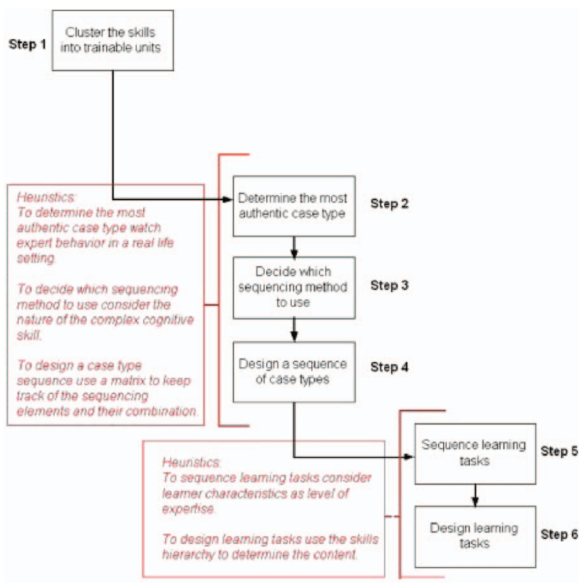

Figure 2b. Fading the strategic support. The partial flow chart presented together with problem 2.

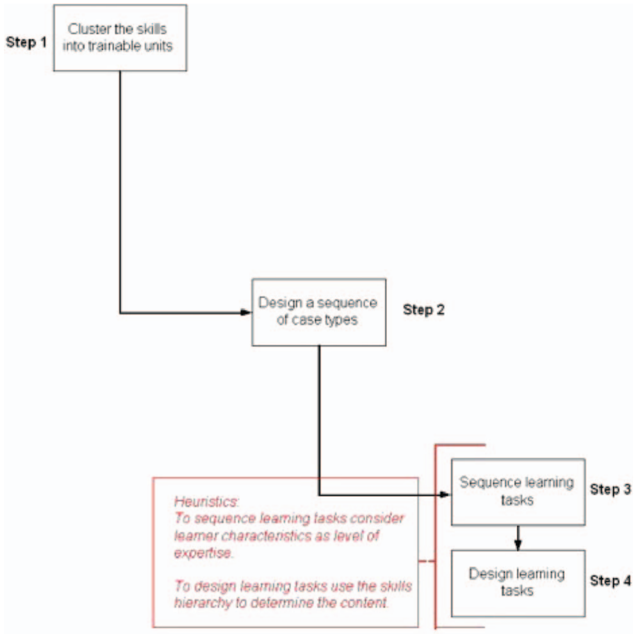

Figure 2c. Fading the strategic support. The partial flow chart presented together with problem 3.

Test items

Twelve test items were administered to the participants. These test items also consisted of multiple-choice questions with four answering options. Six of the 12 test items – equivalent test items – presented short problem descriptions for which the topics were the same as the topics used in the problems presented during practice. They pertained to constructing a skills hierarchy, developing case types, and designing learning tasks. The equivalent test items, thus, made use of the same body of information as the problems during practice. The other six test items – transfer test items – also presented short problem descriptions but, the topics of these problems were different from those used in the problems presented during practice. The transfer items pertained to clustering skills, presenting information, and part task practice. The transfer test items, thus, made use of a different body of information as the problems encountered during practice. The equivalent test items were designed to determine whether the participants had formed specific schemata to help them answer the familiar test items. The transfer test items were designed to determine whether the participants were able to construct specific schemata plus general schemata that help them answer the unfamiliar test items.

Mental effort measurement

Mental effort was used as an index of cognitive load. It refers to the amount of working memory capacity allocated to problem solving. Mental effort was measured using Paas' (1992) nine-point rating scale that ranged from very, very low mental effort (1) to very, very high mental effort (9). Participants were asked, 'How much mental effort did you have to invest to solve the preceding problem?' and 'How much mental effort did you have to invest to solve the multiple choice questions?'

Questionnaire

An exit-questionnaire consisting of six multiple-choice questions with four answering options was administered to the participants. Three questions were related to the participants' motivation (that is, 'Did you seriously study the information that you consulted?', 'Did you do your best to solve the tasks?' and 'Did you consider the 4C/ID course interesting?') and three questions were related to the usefulness of support provided ('Did you have difficulty finding the information needed to solve the task?', 'Did the conceptual support help you find the right information while solving the tasks?' and 'Did the strategic support help you find the right information while solving the tasks?').

Procedure

The participants who took part in this experiment ($N = 92$) received an email explaining the purpose of the mini-course, what student-centered learning entails, the learning elements involved in the mini-course, how to navigate within the mini-course and the experimental rules (that is, work uninterruptedly, do not print or make notes of the available information, and stick to the time schedule). This time schedule was provided in the same email (that is, 35 minutes per problem; 10 minutes per practice item; 20 minutes for the equivalent test items, 20 minutes for the transfer test items and five minutes for the questionnaire) and the participants themselves were responsible for following it.

After receiving this email, participants could start the experiment at a moment that was most convenient for them within a four-week period. The experiment started after logging on to the website of the mini-course. The majority of participants ($n = 51$) eventually refused to actually log on within that four-week period reducing the number of actual participants to 41. Since the random assignment of participants to the four conditions was carried out after signing up for the experiment, the effects of this drop-out caused unequal cell size of the conditions.

After logging on, two windows appeared. One presented the problem (see Figure 3a), the other a list of links to chapters and sections of the hypertext learning materials (see Figure 3b) preceded by the conceptual and strategic support. After completing each problem, the participants filled in the mental effort measure ('How much mental effort did you have to invest to solve the preceding problem?') and subsequently answered four practice items, after which another mental effort measure is filled in ('How much mental effort did you have to invest to solve the multiple-choice questions?'). This learning and practice was followed by the six equivalent test items, a mental effort measure for the equivalent test items, the six transfer test items, a mental effort measure for the transfer test items and, finally, the questionnaire. The participants were not able to browse back in the environment, could only fill in the multiple-choice questions once and, had no access to the information links and support while answering the multiple choice questions.

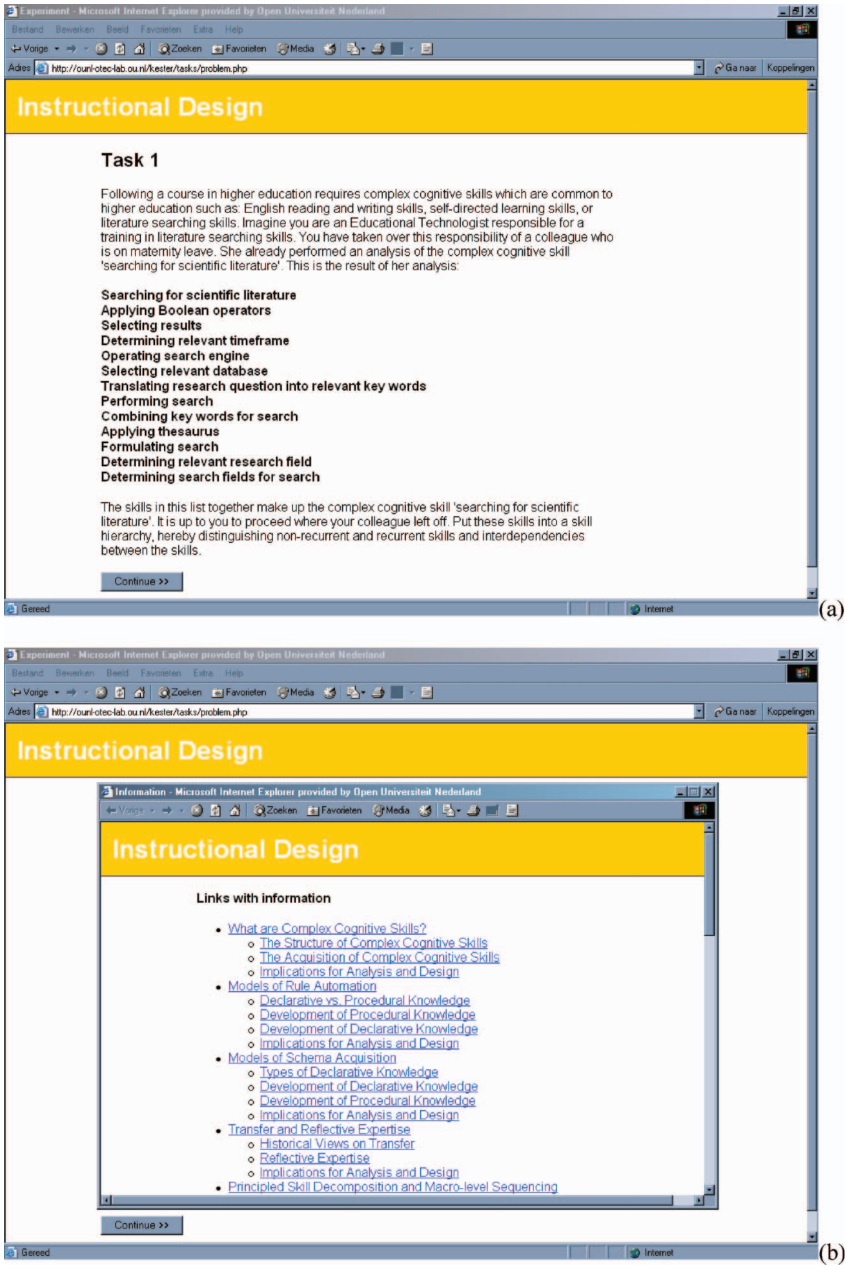

Figure 3. A screen dump of a problem window (a) and a screen dump of the information links window (b).

Results

The hypotheses were tested using a non-parametric Kruskal-Wallis test due to the small sample size. An alpha level of 0.05 was used for all statistical tests. For an overview of the results see Table 1.

Table 1. Overview of the results.

	ConS-StratS $n = 8$	ConSF-StratS $n = 11$	ConS-StratSF $n = 10$	ConSF-StratSF $n = 12$
		Mean rank		
Navigation-accuracy*	15.38	19.45	17.65	28.96
Practice time on task	17.88	24.09	21.75	19.63
Test time on task	13.94	23.36	23.65	21.33
Practice items	16.13	22.68	23.70	20.46
Equivalent test items	26.13	17.55	18.20	23.08
Transfer test items	20.31	17.23	21.50	24.50
ME problems	19.81	21.05	21.95	20.96
ME practice items	22	23.36	20.45	18.63
ME equivalent items	20.88	19.82	21.75	21.54
ME transfer items	20.13	23.91	19.45	20.21

Notes: $^*p < 0.05$.
ConS = Conceptual Support not faded; StratS = Strategic Support not faded; ConSF = Conceptual Support Faded; StratSF = Strategic Support Faded; ME = Mental Effort.

Navigation-accuracy

Significant differences on navigation accuracy were found for condition on navigation-accuracy using a Kruskal-Wallis test (H (3) = 8.19, $p < 0.05$). Multiple comparisons using a Conover-Inman test on ranks – comparable to the parametric Fischer LSD test (Conover, 1999) – showed a significant difference between the 'conceptual support faded, strategic support faded' condition and: (a) the 'conceptual support not faded, strategic support not faded' condition; and (b) the 'conceptual support not faded, strategic support faded' condition on navigation-accuracy ($t(37) = 2.03$; $p < 0.05$). The direction of these differences can be inferred from Table 1 and indicates that the 'conceptual support faded, strategic support faded' condition (*mean rank* = 28.96) has a higher navigation-accuracy than the 'conceptual support not faded, strategic support not faded' condition (*mean rank* = 15.38) and the 'conceptual support not faded, strategic support faded' condition (*mean rank* = 17.65). The difference between the 'conceptual support faded, strategic support faded' condition and the 'conceptual support faded, strategic support not faded' condition matched the alpha level ($t(37) = 2.03$; $p = 0.05$).

Time on task

No significant differences between conditions were found for either the time on task during practice, or the time on task during the test.

Practice items

No significant differences between conditions were found for participant scores on the practice items (H (3) = 2.14, $p = 0.54$).

Test items

Equivalent test items

No significant differences between conditions were found for the participant scores on the equivalent test items (H (3) = 3.42, $p = 0.33$).

Transfer test items

No significant differences between conditions were found for the participant scores on the transfer test items (H (3) = 2.34, p = 0.51).

Mental effort measurement

Mental effort during practice

No significant differences between conditions were found for the mental effort scores while studying the practice problems and for the mental effort scores while answering the practice items.

Mental effort during the equivalent test

No significant differences between conditions were found for the mental effort scores while answering the equivalent test items.

Mental effort during the transfer test

No significant differences between conditions were found for the mental effort scores while answering the transfer test items.

Questionnaire

For an overview of the questionnaire results see Table 2. A Chi-square test for independent samples yielded no significant differences between main factors for the answers on the questionnaire. The majority of the participants seriously studied the mini-course, they did their best and considered the mini-course to be interesting. Most of them reported difficulty with regard to finding relevant information and they thought both types of support were moderately helpful.

Discussion

This study confirms the hypothesis that fading problem-related support helps learners to navigate through a hypertext document more accurately. Learners in an e-learning environment in which the conceptual and the strategic support was faded during practice consulted the correct sections significantly more often than learners in a similar environment in which this support was not faded or in which only the conceptual support or the strategic support was faded. The second hypothesis, that fading support yields a higher practice performance and a higher test performance, is not confirmed. No significant differences were found for performance on the practice items, the equivalent test items and the transfer test items. In addition, the amount of time and mental effort that the learners invested during practice and the test was not significantly different. The results from the questionnaire show that regardless of condition, the majority of learners were quite motivated to complete the course. Although they reported that finding the right information remained difficult for them, the majority stated that the conceptual and strategic support was sometimes helpful to them.

Table 2. Overview of the frequency-distributions per condition on the questionnaire.

	Did you seriously study the information that you consulted?			
	Yes	Not always	No	Don't know
ConS-StratS	1	5	2	0
ConSF-StratS	2	6	3	0
ConS-StratSF	1	6	1	2
ConSF-StratSF	2	8	2	0
	Did you do your best to solve the tasks?			
	Yes	Not always	No	Don't know
ConS-StratS	6	1	1	0
ConSF-StratS	8	2	0	1
ConS-StratSF	8	2	0	0
ConSF-StratSF	8	4	0	0
	Did you consider the 4C/ID course interesting?			
	Very interesting	Moderately interesting	Not interesting	Don't know
ConS-StratS	2	5	1	0
ConSF-StratS	9	1	1	0
ConS-StratSF	4	6	0	0
ConSF-StratSF	8	4	0	0
	Did you have difficulty to find the information needed to solve the task?			
	Yes	Sometimes	No	Don't know
ConS-StratS	6	2	0	0
ConSF-StratS	6	5	0	0
ConS-StratSF	6	3	1	0
ConSF-StratSF	7	4	1	0
	Did the conceptual support help you find the right information whilst solving the tasks?			
	Yes	Sometimes	No	Don't know
ConS-StratS	1	4	2	1
ConSF-StratS	3	5	3	0
ConS-StratSF	0	7	3	0
ConSF-StratSF	1	6	5	0
	Did the strategic support help you find the right information whilst solving the tasks?			
	Yes	Sometimes	No	Don't know
ConS-StratS	1	5	2	0
ConSF-StratS	2	4	5	0
ConS-StratSF	1	6	3	0
ConSF-StratSF	0	8	4	0

Notes: ConS = Conceptual Support not faded; StratS = Strategic Support not faded; ConSF = Conceptual Support Faded; StratSF = Strategic Support Faded.

The question remains why learners in the e-learning environment where the support was faded did not achieve a higher performance. Two explanations seem plausible. First, learners only spent an average of 81.59 ($SD = 11$) minutes on the practice phase which seems to be too short a period of time to get a grip on the subject matter that needs to be mastered in this experiment. This is supported by the findings that the learners obtained an average of 2.68 points ($SD = 1.47$) out of six on the equivalent test items and 2.24 points ($SD = 1.11$) out of six on the transfer test items which could indicate a bottoming effect. A second explanation could be that although the learners in the faded support condition navigated significantly more accurately through the materials than the learners in the other conditions, the proportion of correctly consulted sections of the total of correct sections that *could be* consulted (that is, seven for chapter 6, six for chapter 10, and seven for chapter 11) by the learners, remained rather small (that is, $M = 0.16$, $SD = 0.2$ for the 'conceptual support not faded, strategic support not faded' condition; $M = 0.24$, $SD = 0.2$ for the 'conceptual support faded, strategic support not faded' condition; $M = 0.29$, $SD = 0.17$ for the 'conceptual support not faded, strategic support faded' condition; and $M = 0.23$, $SD = 0.21$ for the 'conceptual support faded, strategic support faded' condition).

To conclude, fading support in student-centered learning environments helps learners to more accurately navigate through electronic resources, in this case a hypertext document. This was, however, not enough to get them to: (1) invest a reasonable amount of time; (2) consult all relevant information; and (3) allocate the cognitive capacity freed by enhanced navigation, to processes relevant for learning. It seems that additional instructional interventions are necessary to elicit learning. Future research should aim for combining problem related support with methods to facilitate learning (for example, self-explanation) in student-centered e-learning environments.

Notes on contributors

Liesbeth Kester is assistant professor at the Educational Technology Expertise Center (Otec) of the Open University of the Netherlands (OUNL). Her research interests focus on learning in adaptive learning environments. In 2006, she received a Fulbright Junior Scholarship and in 2007, she was awarded a grant from the Netherlands Organisation for Scientific Research for her three-year research project on the learning effects of cognitive assessments in adaptive educational systems.

Paul A. Kirschner is professor of Psychology at the Open Universiteit Nederland with a chair in Lifelong Learning and is director of research on Lifelong Learning in the Professions at the Netherlands Laboratory for Lifelong Learning (NeLLL). His areas of expertise include lifelong learning in and for the professions and professionals; computer supported collaborative learning; designing electronic and other innovative learning environments; and media-use in education.

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